

**Figure 1. (Left) View of the Kennicott River (foreground) from the McCarthy footbridge with the illuminated Mesozoic rock sequences (background) towering over the landscape. Rocks of this age make up much of the Wrangell-St. Elias National Park and Preserve.**

Photograph by Andrew Caruthers

**Figure 2. (Above) Silicified coral of genus *Margarosmilia*.**

## From Hot and Tropical to Cold and Arctic: The Triassic History of the Wrangell Mountains

By George D. Stanley, Jr., Andrew H. Caruthers and Robert B. Blodgett

Amidst the bold and unforgiving landscape of endless mountains, a thick and spectacularly exposed sequence of light-colored, sharp, craggy Upper Triassic carbonate rocks majestically rise-up and stand out against a background of short, dark-green, alpine grasses within the confines of the untamed Wrangell-St. Elias National Park and Preserve of southern Alaska, one of many mountainous areas making up Alaska (*Winkler 2000*). In their present situation, it is difficult to imagine that this area once existed underwater, in a tropical marine setting. Buffeted by winds, covered by snow, eroded by the vicissitudes of ice and relentless glaciers, these massive outcroppings of limestone have been carved into the magnificent scenery now characterizing much of the park. However, some 220 million years ago during Late Triassic time they were deposits on top of thick volcanic flows in the middle of an ancient ocean called Panthalassa.

The vast Panthalassan Ocean covered one half of the world, and the present-day Pacific is all that remains of this

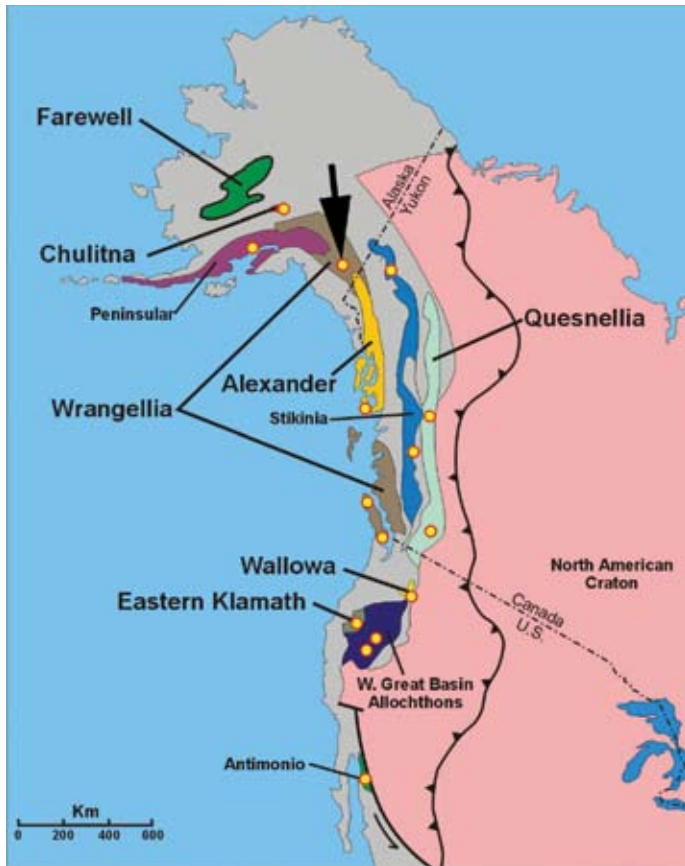
once much greater ocean. Undersea volcanoes produced massive amounts of lava (11,500 feet/3,500 m thick) called the Nikolai Greenstone, which piled up and eventually broke the surface of the ocean, emerging as small clusters of volcanic islands. Massive amounts of carbonate rock called the Chitistone and Nizina Formations provide record of the geologic history. Now compressed and hardened into rock more than 3,500 feet (1067 m) thick, these rocks represent sediment on top of the volcanic islands. Sediment of this character often formed slopes, reefs with shallow lagoons, and tidal flats. Warm tropical waters were teaming with marine life, including many reef-dwelling organisms like sponges, corals and mollusks.

The complex task of deciphering the unique geological history of the Wrangell Mountains began as a collaborative effort by a team of U.S. Geological Survey (USGS) geologists—E. M. MacKevett Jr., A. K. Armstrong, N.J. Silberling, and many others—in the 1960s and early 1970s. Their effort was largely responsible for mapping and describing the rock units exposed in the Wrangell-St. Elias, and interpreting their deposition from Late Paleozoic

to Mesozoic time (*MacKevett 1965, 1970, 1974, 1976; Armstrong et al. 1969; Armstrong and MacKevett 1982*). Once mapping and field descriptions of the Wrangell-St. Elias was completed, the stage was set for more detailed comparative study of individual rock units and tectonic, sedimentary, paleontologic, and paleomagnetic analyses. As studies progressed it became evident that these rocks were formed in a setting bearing no resemblance to other fault-bound blocks. Furthermore, it also became apparent that these rocks were exotic to North America and had been displaced considerable distances since their formation.

Two studies in particular were instrumental in deciphering remnant magnetism to deduce just how far the Wrangell Mountains have traveled since being deposited. Hillhouse and Grommé (1980) and Yole and Irving (1980) analyzed the natural remnant magnetism using the orientations of magnetic minerals in basalt lavas that erupted during Triassic time. These data from volcanic rocks, compared with polar wandering and the present-day paleopoles, indicated formation between 15 and 18 degrees of the paleoequator—far from their present-day





**Figure 3. Generalized map of western North America showing approximate positions of various displaced terranes in their modern-day location. Arrow indicates study area for this paper; yellow circles are approximate locations of known Late Triassic fossiliferous marine localities. Figure adapted from Coney et al. (1980).**

location. Fossils and carbonate rock units gave clear evidence of tropical to subtropical settings and lack of contamination by land-derived sediment suggested that the rocks were formed at some distance from the North American continent. Exact paleolongitude however were more difficult to decipher. Longitudinal positions in the ancient Pacific Ocean and exact distance from the ancient North American margin were suggested to have been far. Resolving a particular hemisphere in which the volcanic rocks formed is difficult and both a northern hemisphere and southern hemi-

sphere were discussed. In the case of the latter, it would imply a remarkable change in latitude as the nearest comparable fossils and rock types reside in South America.

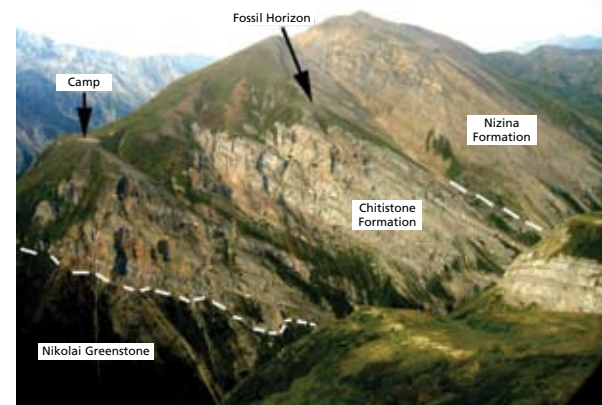
One of the spin-offs of plate tectonics was the realization that numerous bits and pieces of ancient real estate formed as volcanic islands in the ancient Pacific Ocean. Driven by the relentless forces of ocean sea-floor spreading, these fragments moved considerable distances, being subsequently transported along the North American seaboard via faults, eventually reaching

very high latitudes. Some of these rocks contained fossils matching up closely with Asia and central Europe. These fragments or blocks were called “exotic” or “displaced” terranes and produced a crazy-quilt pattern when mapped geologically (Figure 3). Many were oceanic in origin, existing as volcanic island arcs, similar to reef-fringed volcanic islands that dot the Pacific Ocean today. The concept of displaced terranes helped make sense of the crazy-quilted pattern of geology common throughout western North America (Coney et al. 1980).

Geologists of the USGS made the exotic terranes of Alaska known in the 1970s, with basic concepts emanating from systematic field mapping in remote portions of Alaska, as well as in western conterminous United States (Jones et al. 1977). Canadian geologists continued their studies of western interior Yukon Territory and British Columbia, Canada. Before advent of plate tectonics, workers such as J.P. Smith (1912, 1927) attempted to explain occurrences of Triassic fossil corals in southeastern Alaska by hypothesiz-

ing an expanded tropical belt extending from the equator to high latitudes near the poles in Triassic time, but that idea was put to rest after the emergence of plate tectonic theory. The concept of displaced terranes made better sense of anomalous, high-latitude occurrences of coral reefs.

After over 30 years of field investigations and mapping, geologists have come to interpret a diverse and tectonically active history for much of the North American Cordillera. This rather large and extensive area of western North America is now known to contain numerous tectonically displaced terranes preserved in mountain belts running from Sonora Mexico to Alaska, some of the more common terranes are shown in Figure 3. Some of these far-flung terranes are suggested to have traveled over thousands of miles across the ancient Panthalassan Ocean. Sequences of rock in the Wrangell Mountains of southcentral Alaska represent the northern part of one of the best known and most widespread of displaced terranes, designated “Wrangellia.”



**Figure 4. Photograph showing the east side of Green Butte in the Wrangell Mountains. Three distinct rock formations (Nikolai Greenstone, Chitistone Formation and Nizina Formation), making up the Triassic stratigraphy, are identified. Dashed line indicates formation boundary; arrows depict location of camp and fossil locality.**

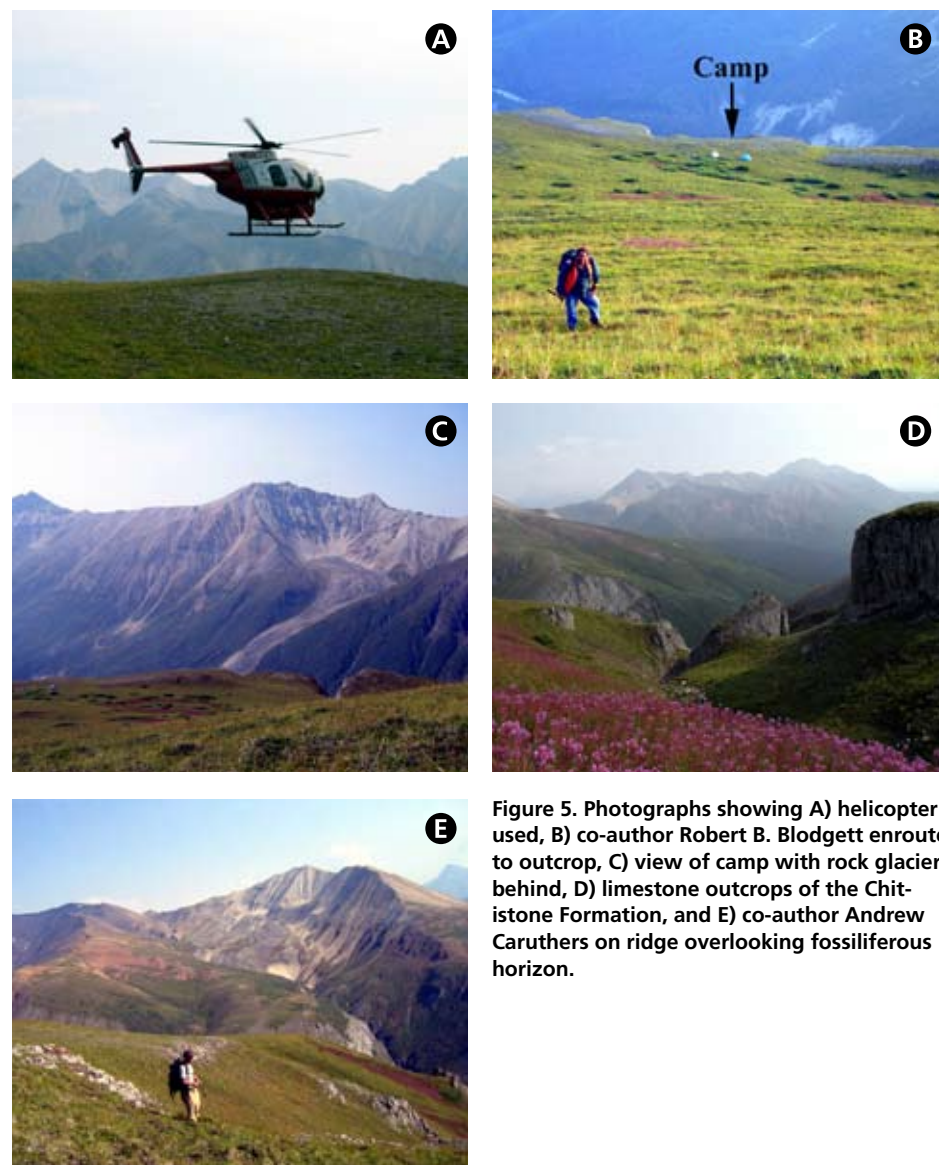
Following formation, Wrangellia broke apart and was propelled northward along lateral faults, eventually residing in present-day latitudes of Alaska and western Canada. Presently, bits and pieces of Wrangellia extend far to the south, comprising modern day Queen Charlotte Islands and Vancouver Island of western Canada, and even the Wallowa Mountains in eastern Oregon (*Jones et al. 1977*).

During their northward journey, terranes of the North American Cordillera carried fossils as cargo in their stratigraphic successions. These fossils show paleobiogeographic alliances with distant regions such as the ancient Tethys—a now vanished tropical east-west seaway cradled in the arms of the one-world ancient continent called Pangea. During the Triassic the Tethys existed as a shallow to deep-water marine embayment containing a high-diversity of fauna including corals, mollusks, foraminifers and many other invertebrate groups that are remarkably similar to those found in stratigraphic successions of the North American terranes. Although somewhat rare, vertebrate remains also occur and include fish scales and teeth, the small tooth-like dentitions known as conodonts, as well as larger bones of swimming marine reptiles including fish-like ichthyosaurs and long-necked plesiosaurs. The mere presence of these ancient relics of a once tropical life has proven valuable to reconstructing ancient geography.

Unfortunately volcanic and tectonic forces, characterizing most terranes, result in destruction of valuable fossils. Without well-preserved fossils, paleon-

tologists cannot accurately identify species and correlate coeval faunas. Nor can they solve the anomalies of paleogeography and ancient environment. Even without geologic pressure and heat, shallow-water fossils preserved in limestone are normally subjected to recrystallization, which destroys delicate microstructure rendering fossils difficult to identify. However, in certain key beds of island arc terranes, such as a fossiliferous horizon at Green Butte in the Wrangell Mountains, silica replacement of the original calcareous shells has preserved important details in these shelly fossils. Immersion in weak acid baths dissolve the enclosing carbonate matrix, leaving behind perfect three-dimensional fossils; many of which can be identified with accurate precision. Such beds are valuable as paleontological “gold mines” because they provide a wealth of information normally unavailable.

Original field mapping of Triassic rock at Green Butte, high above McCarthy, Alaska, revealed a distinctive horizon of silicified marine fossils sandwiched at the boundary (or contact) in between the Chitistone Formation and the Nizina Formation (*Figure 4*). From previous USGS collections from this bed, Montanaro Gallitelli et al. (1979) described some of the silicified corals. In a separate study, Newton (1983b) described the bivalves. These studies found previously unrealized similarity between these corals and coral faunas from other displaced terranes as well as with similar aged counterparts of the former Tethys region. The studied bivalves revealed an especially strong connec-



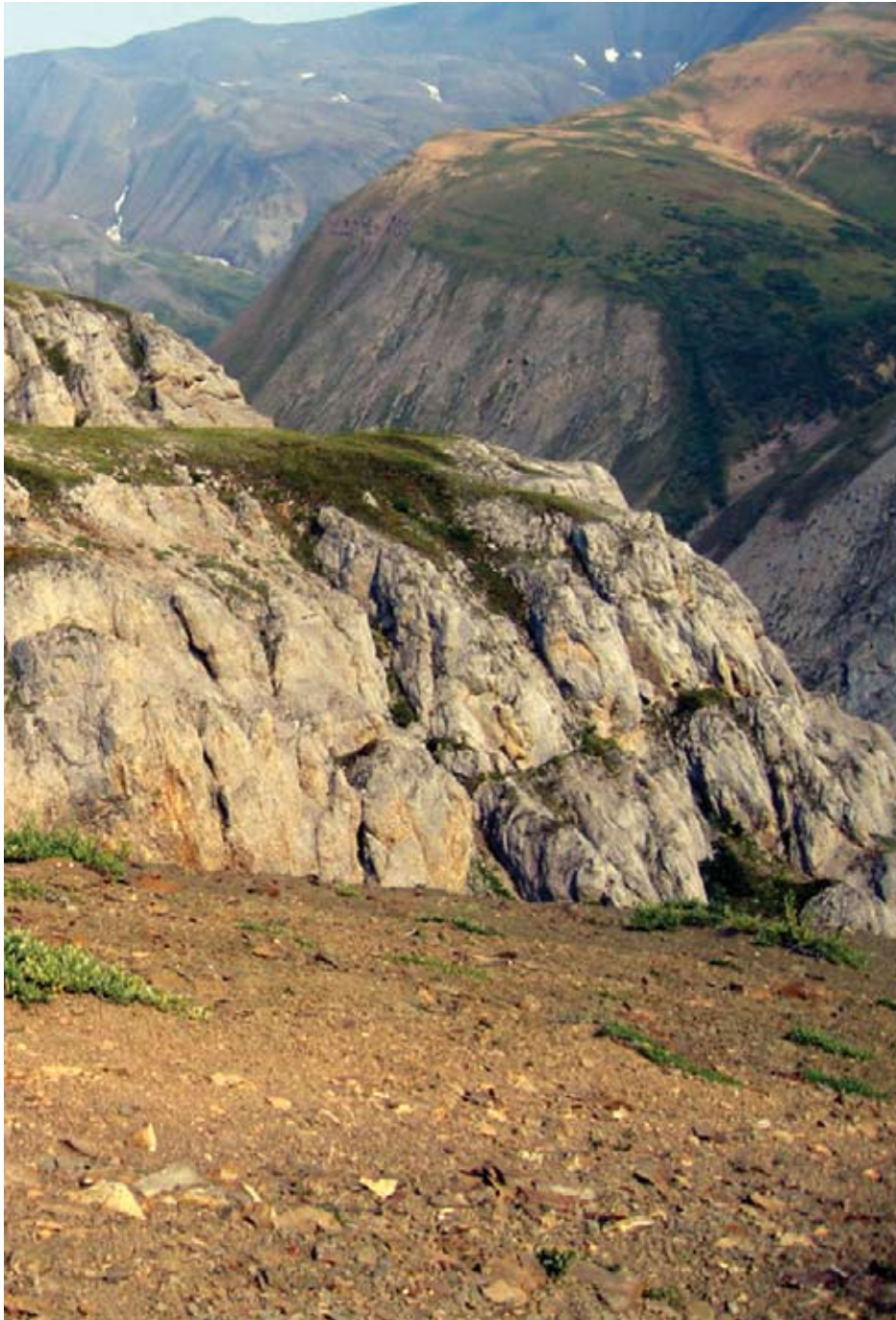
**Figure 5.** Photographs showing A) helicopter used, B) co-author Robert B. Blodgett enroute to outcrop, C) view of camp with rock glacier behind, D) limestone outcrops of the Chitistone Formation, and E) co-author Andrew Caruthers on ridge overlooking fossiliferous horizon.

tion with bivalve species in the Wallowa Mountains, Oregon. This correlation re-opened the door to the original claim by Jones et al. (1977) that large fragments of Wrangellia have been distributed over

wide areas by plate tectonic processes. Careful study of the rock types and fossils allowed the rock sections to be correlated over such great distances.

During the summer of 2004, a team of





Photographs by Andrew Carthers



Figure 6. (Left) Fossiliferous horizon at the boundary between the Chitistone Formation and Nizina Formation at Green Butte, Wrangell Mountains. (Top) Lateral view with co-author George Stanley Jr. for scale. (Bottom) Down-slope view of outcrop with flagging tape for scale.



paleontologists, authors of this article, set out to reinvestigate the Triassic portion of Wrangellia at Green Butte. Our overall goal was to gather a sense for the faunal diversity, paleoecology and depositional environment and to interpret conditions of life in the ancient sea surrounding Wrangellia some 220 million years ago. With the aide of helicopter support (*Figure 5a*), we collected large blocks of silicified limestone. By processing many large blocks of this fossiliferous limestone and studying the resulting material, we were able to gather new information on taxonomic diversity, significantly increasing our knowledge of fossils from this site.

After an exhilarating helicopter ride from the town of McCarthy, we reached the southeastern shoulder of Green Butte, set up camp, and started the search (*Figure 5*). While traversing across the eastern face of the mountain, we used clues in the surrounding geology to locate this important bed of rock. Then, upon descending down a rather steep and unstable talus slope, a small knobby-looking outcrop (approximately 30 feet/9 m wide) emerged below. We immediately knew we had found it; this outcrop stood out from all others at Green Butte by the sheer abundance of silicified fossils jammed together in haphazard fashion, standing out in relief against the dull grey rock matrix (*Figure 6-7*). Shallow-water marine organisms, immaculately well preserved in an eerie, almost ghostly state were so prevalent and congealed that deciphering between individual samples we wished to collect

was difficult, as we wanted to keep them all.

While scampering across the face of this knobby-looking outcrop, we used our hammers and pry-bars to crack off limestone blocks for processing and began to pull various pieces of evidence together; slowly forming hypotheses surrounding this ancient relic of oceanic life. Clues revealing just how these fossils became trapped or “frozen” in time started to circulate through our minds as a new story of deposition emerged. The jumbled and inconsistent orientation of fossils (*Figure 7a-d*), the evident scour at the base of the outcrop (*Figure 8*), and the presence of large fine-grained areas of muddy carbonate almost completely devoid of fossils except for instances where lenses have been incorporated (*Figure 9*) all point to one conclusion. These fossils had been transported down-slope as a massive debris flow. The random, highly fragmented, orientation of fossils suggests downslope movement and the scour at the base suggests a sudden underwater avalanche-type of event. Deformed limy “blobs” with occasional fossil lenses indicate the incorporation of shells in soft carbonate mud lumps while rolling down a steep slope. All told, debris flows along the margin of this part of Wrangellia were responsible for transporting thousands of shallow-water organisms from their original living environment on the shelf into deeper-water (*Figure 10*).

During much of the Mesozoic era tropical reef ecosystems of high diversity inhabited the now vanished

**Figure 7. Close-up photographs of fossiliferous limestone, showing highly fractured, inconsistently oriented state of fossils. Photographs A and B represent the top of the deposit whereas C and D are taken in the middle section. All photos are uniform without any evidence of their being multiple depositional events.**

seaway called the Tethys. Today remnants of this ancient seaway are especially well preserved in the Alps of central Europe. During Triassic time, vast reef complexes inhabited the Tethys; however, across the Panthalassan Ocean in distant Wrangellia, expansive reef complexes did not develop. This could have been caused by conditions of lowered nutrients, poor water circulation, or the influx of fine-grained volcanic sediment. Nevertheless, identical or very similar Tethyan species of corals (*Figure 11*), gastropods, bivalves, ammonoids, echinoderms (sea urchins and crinoids), calcified sponges, spongiomorphs, and calcified algae occur at Green Butte (*Figure 12*). Bone fragments (likely of reptilian origin), fish teeth and scales, as well as microscopic conodonts (small tooth-like structures) also are found and were part of the swimming open-water fauna that flourished in the tropical ecosystem of Wrangellia. Even though true reefs were absent, corals and sponges created small-scale buildups a couple of yards thick. Corals common in modern day tropical marine environments are sessile benthic creatures living attached on the ocean floor, killing their microscopic prey with stinging tentacles. Finding



Photographs by George Stanley Jr.





Photograph by George Stanley Jr.

**Figure 8.** Photograph showing the non-uniform basal scour of the deposit, dashed line indicates scour. Note limestone below dashed line is relatively devoid of fossils, whereas limestone above is packed with broken up fossils, except for large fine-grained area containing muddy carbonate with a fossiliferous inclusion.

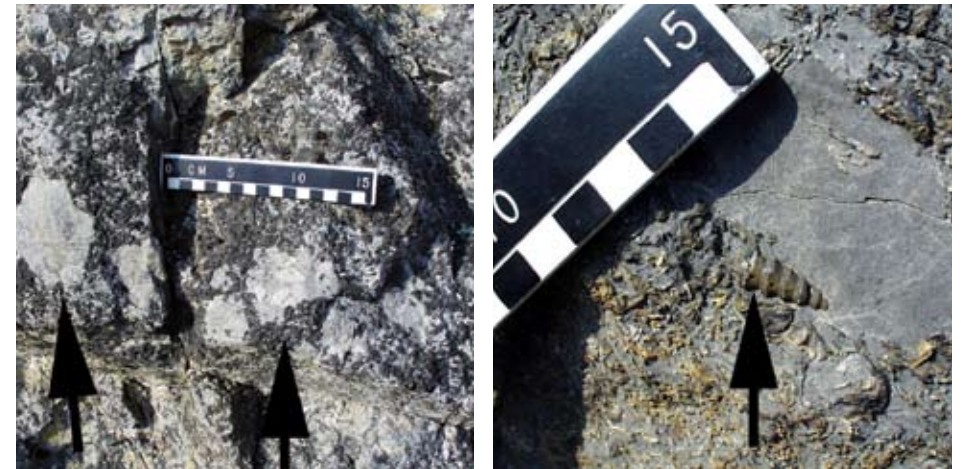
corals and associated fossils in their original environment hold valuable clues such as water clarity, nutrient level, sunlight, water temperature, and depth—all vital for reconstructing paleoenvironment.

How the sea creatures disperse themselves also is important to reconstructing ancient geography. It is clear that as adults, many organisms like snails, spiny echinoids and other bottom-dwellers can move about on the ocean floor but cannot travel vast distances. As juveniles in their larval stages, however, most of these sea creatures existed as

microscopic swimming or floating plankton that were capable of being transported immeasurable distances by water currents; not only between volcanic islands, but also across the expansive Panthalassan Ocean from the western Tethys. Our research utilizing modern faunas suggests that certain species of corals are “broadcasters” and produce offspring capable of wide dispersal while other corals are “brooders” whose larvae do not have the capability of wide dispersal. Furthermore, a certain group of snails called archaeogastropods do not have a free-swimming larval stage;



Photographs by George Stanley Jr.



**Figure 9.** (Top) Large, un-fossiliferous, fine-grained lenses of muddy carbonate, trapped in fossiliferous horizon. (Bottom) Lenses sporadically contain fossiliferous inclusions (arrows) indicating down-slope movement as an underwater debris flow.



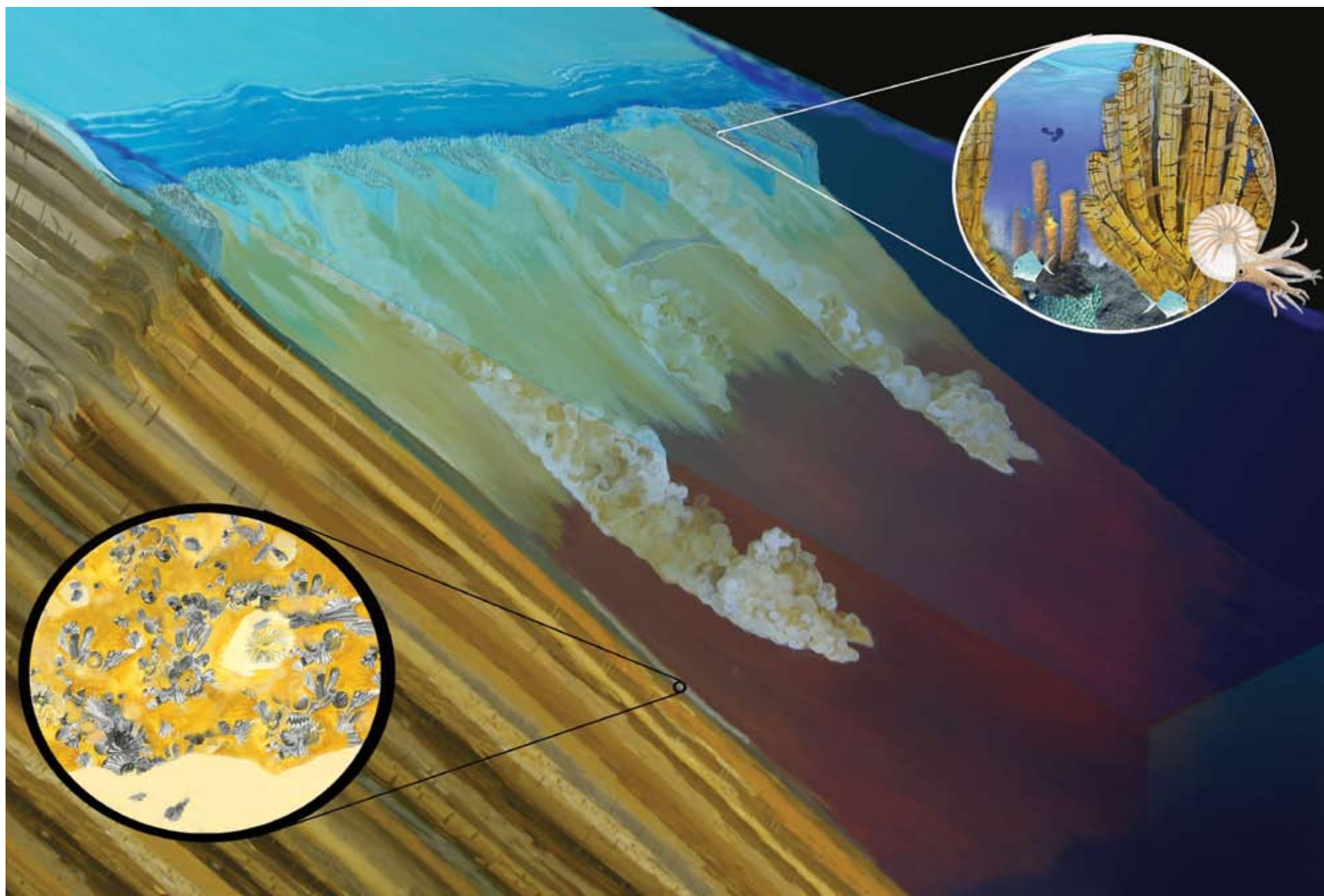
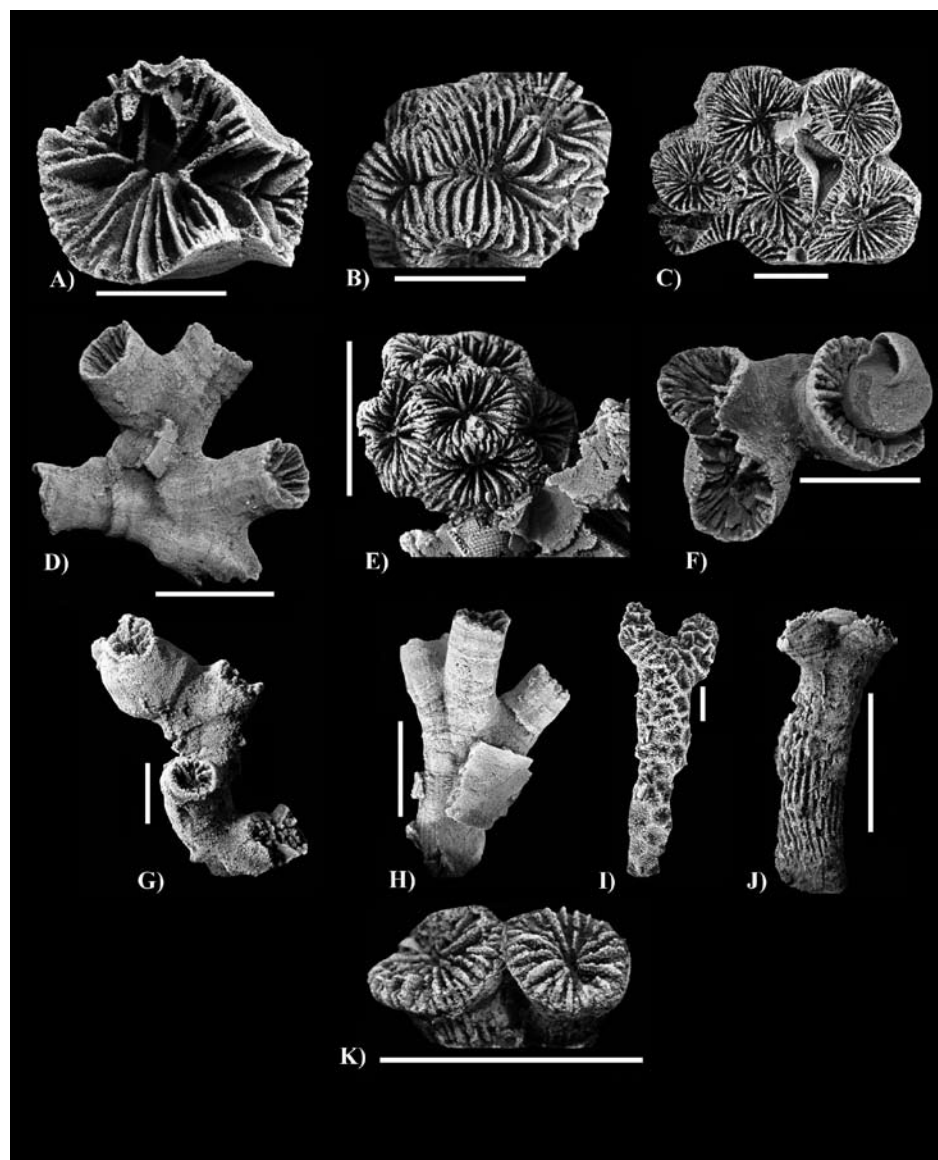


Figure 10. Illustration of Late Triassic Wrangellia depicting fossiliferous horizon before, during, and after debris flows, responsible for creating this valuable deposit. Rendition also shows the multitude of organisms recovered during acetic acid processing.





Photograph by Andrew Gauthier

Figure 11. Composite photograph showing silicified corals obtained from the collected limestone blocks, from Green Butte. Corals identified from genera *Paracuifia* (A), *Pamiroseris* (B), *Margarosmilia* (C,K), *Retiophyllia* (D, F, G, H, J), and *Distichomeandra* (E, I). Scale bar is 0.39 inches (1 cm).

so do not take up life drifting about with the water currents. These types of sea creatures are extremely important in reconstructing ancient geography due to their “endemic” nature. Thus, recognizing endemic species is vital for deducing paleogeographic relationships between terranes.

Armed with valuable data from the identified coral and gastropod species at Green Butte, we began our comparative analysis of similarity. For this we turned to the world of statistics, testing coral species found at Green Butte with coral fauna (of a similar age) from other displaced terranes of the North American Cordillera. We compared the Green Butte coral species with species from the Alexander terrane (another terrane comprising much of present day southeastern Alaska) as well as with fauna from the Peruvian Andes, which yielded low levels of similarity. Interestingly a similar statistical comparison of slightly younger corals from the southern Wrangellian counterpart (Vancouver Island), produced a surprising amount of similarity with Peruvian corals, implying that during the Late Triassic this portion of Wrangellia could have been located closer to South America than previously thought. We also noted an inordinate amount of overlap between Green Butte corals and species from the Willowa terrane (Willowa Mountains, Oregon). This connection was evident as well in the recovered snails. Paleontologically, this Wrangellia/Willowa terrane connection was first noted by Newton (1983a), who studied Triassic clams from Green Butte as part of her doctoral thesis and later men-

tioned by Stanley (1987), concerning the associated reef-like ecosystem of the Blue Mountains of northeast Oregon.

Systematic study of the collected and processed fossils from the Wrangell Mountains reveals a complex and interesting story, allowing us to test ideas about paleogeography tectonic hypotheses and ancient environments. Most of the silicified fossils from Green Butte were reworked—mixed and transported down an ancient depositional slope, but they once existed in shallow-water setting of Wrangellia. These fossils provide a strikingly detailed snapshot of the diverse near-shore, shallow-water tropical marine ecosystem that inhabited the vanished volcanic islands of Wrangellia.

But where were these ancient volcanic islands situated? Research suggests that they existed in a remote setting, at a yet undetermined distance offshore the continent of North America. Paleomagnetic studies and a degree of similarity to fossils of distant Tethys Sea suggest a tropical position far to the south. Therefore, rocks of the Wrangell Mountains were moved thousands of miles northward out of the tropics to their present location in temperate southern Alaska. The established overlap in coral, snail, and bivalve species with the Willowa terrane confirmed speculation by geologists more than 25 years ago that Wrangellia is composed of rocks spread along the western margin of North America as far south as northeastern Oregon (Jones *et al.* 1977).

As briefly mentioned above, simi-

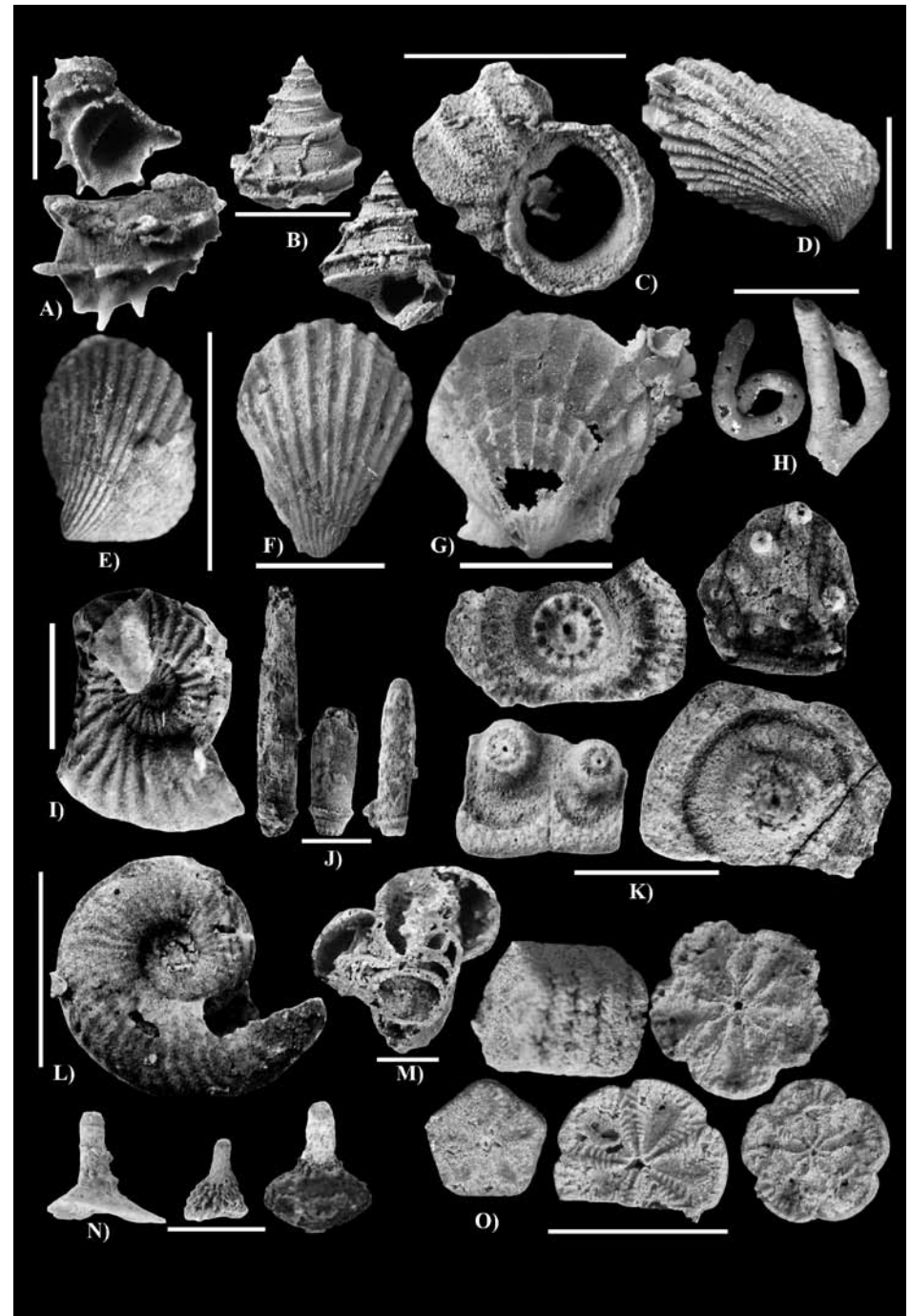


Figure 12. Composite photograph of diverse invertebrate fauna acquired from dissolved limestone blocks at Green Butte. Identified fossils include: (A) a young gastropod, genus *Spinidelphinulopsis*, known from the Wallowa, Wrangellia, and Alexander terranes; (B) the widespread gastropod, genus *Chartroniella*, known throughout the Western Hemisphere from Peru, the Wallowa terrane and northern Wrangellia; (C) the neritimorph gastropod, genus *Nuetzelopsis*, known from both Wrangellia and the Wallowa terranes; (D) strongly ribbed bivalve from genus *Septocardia*; (E) strongly ribbed bivalve, genus *Palaeocardita*; (F) Limid bivalve, possibly genera *Mysidoptera*; (G) left valve of a possible *Oxytomid* clam; (H) 2 annelid worm tubes belonging to a group called serpulids worms that secreted tubes on either hard substrate or shell debris; (I) coiled ammonite, extremely useful in providing constraints on relative age for the surrounding rock bed in which they are found; (J) 3 straight echinoderm sea urchin spines, functioned to provide protection against predators and were attached to the surface of the internal skeleton or shell; (K) 4 echinoderm sea urchin plates (or internal skeleton, shell) belonging to several different species; (L) coiled ammonite; (M) a chambered, calcified demosponge, such sponges are very rare in silicified beds due to their fragile skeletons; (N) 3 bulbous echinoderm sea urchin spines; (O) crinoid (sea lily) ossicles, another group of echinoderm whose calcite plates stacked together likes checkers to produce long flexible stems serving to attach the calyx or head, which has yet to be found in the deposit. Scale bar is 0.39 inches (1 cm). Bivalves E-G identified by Tom Waller.

lar aged rocks and fossils from another Alaska terrane near Ketchikan (the Alexander terrane, Figure 3) were studied during our project. Alexander terrane fossils and associated rock sequences show lower similarity with those of Wrangellia (Blodgett and Frýda 2001, Caruthers 2005, Caruthers and Stanley 2008), despite the fact that some geologists previously had postulated a geologically gigantic, contiguous Alexander/Wrangellia block called a superterrane. A super terrane theory is based strictly on geologic and tectonic evidence, suggesting Wrangellia was tectonically stitched to the Alexander terrane about 100 millions years earlier than the Triassic—in mid-Paleozoic time (Gardner et al. 1988). Our findings call this hypothesis into question. Further testing of course will require more investigation into the respective geologic histories, extracting both paleontologic, stratigraphic, tectonic and

geophysical data from both of these terranes.

Paleontology can produce exciting, stimulating and sometimes unexpected results. The silicified fossils we studied in the Wrangell Mountains had lain in their limestone tombs for over 200 million years before they were discovered and collected. Freed by acid etching and studied systematically, they provided details for geographic relationships of greater Wrangellia. Before becoming tectonically incorporated into the North American continent, Wrangellia had a long and complex history. Identification and similarity calculations using the fossil taxa, along with knowledge from living counterparts, has given us a better understanding of the ancient ecology and geography. It is testimony to the dynamic nature of our planet and the relentless forces of plate tectonics, especially those that formed the most famous displaced







Photograph by George Stanley, Jr.

**Figure 13. Thick Upper Triassic limestone is spectacularly exposed resting above volcanic rocks in the Wrangell-St. Elias National Park and Preserve.**

terrane making up the Wrangell-St. Elias National Park and Preserve.

Current hypotheses accounting for this terrane are many. They suggest several alternatives for Wrangellia and the Alexander terrane. These include: 1) Both terranes evolved separately as volcanic island arcs near the North American continent, 2) they evolved separately but existed far from North America and traveled unknown distances within the

Panthalassan Ocean before they were incorporated into North America, and 3) Wrangellia was scraped off South America, fragmented and then moved thousands of miles northward to its present location along the North American margin. An even more exotic idea derives Wrangellia (and perhaps other terranes as well) from “source” rocks in Siberia and the Russian Far East. After having moved from the tropics of the

eastern Tethys, these exotic rocks may have been translated along faults, similar to the San Andreas of California, to make a journey of many thousands of miles around the Pacific rim, eventually arriving at their present sites in Alaska and western North America.

From a hot and tropical ancient ecology to the cold and Arctic weather where their remains now are found, dead sea life has an interesting tale to tell.

Paleontologists continue putting the dead to work to help reveal ancient geography. We expect that the fossils of Wrangellia will continue working for us, revealing more clues about how Alaska and the rest of western North America was made through complex movements of displaced terranes.



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